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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 802

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER December 29, 1919

# QUALITY AND VALUE OF IMPORTANT TYPES OF PEAT MATERIAL

## A CLASSIFICATION OF PEAT BASED UPON ITS BOTANICAL COMPOSITION AND PHYSICAL AND CHEMICAL CHARACTERISTICS

By

ALFRED P. DACHNOWSKI, Physiologist
Soil-Fertility Investigations

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## THE PRESENT STATUS OF PEAT UTILIZATION.

The problem of peat utilization may be analyzed from several points of view, but only a few aspects of the subject are of essential importance to emphasize at this time. Among the peat problems in question none, in the opinion of the writer, is so serious as the failure to realize the existence of the important grades or types of this material in regard to quality and their relative value for agriculture or other uses.

There is a growing recognition of the fact that the term "peat" is too general to be applied to plant remains essentially different in composition, which have different agricultural and technical possi-

bilities, and which vary greatly according to regional distribution and topographic features, even in the same deposit. Not only a proper understanding by the layman appears to be wanting, but the necessary scientific foundation is still lacking in this country which would deal with the differences in botanical composition of the various peat materials and their corresponding physical, chemical, and other characteristics of practical importance to the farmer, the technician, the manufacturer, and the scientist as well. A recognition of these differences, it is believed, would emphasize to those using peat land the inherent possibilities and limitations of the organic materials. From the standpoint of the State agencies and local investigators this is a specific problem of an urgent character underlying the sound and rational use of such land. Neither the selection of peat deposits of practical value for certain crops or for specific technical purposes nor the close correlation which exists between the botanical composition of the different peat materials and its corresponding physical, chemical, cultural, economic, or other merits can be attempted successfully until consideration is given to the important types of this material found in this country.

It is precisely this information which would enable one to form a correct judgment concerning the structural profile of peat deposits which accumulate under the widely differing climatic, topographic, geologic, and vegetational conditions of this country; and it is this aspect of the problem that would supply the essential criteria concerning the manner of developing a peat area for specific agricultural or technical purposes, or for a combination of agriculture with a varied manufacturing utilization, where under the pressure of strenuous circumstances this development must needs be centralized near a source of supply of raw material to insure financial success.

If we attempt to formulate the status of peat investigations in the United States and compare it with that of Holland, Sweden, Austria, or Germany; if we appraise in these countries and our own the degree of success in utilizing the various types of this material directly applicable to certain forms of agriculture or to economic industries; or if we compare the respective results of scientific investigations and the literature on the subject, based upon well-established, definitely described classes of deposits or groups of peat material, we shall have to acknowledge that we are far behind the position we ought now to occupy by right of resources and opportunities. The lack of information on which a wise decision should be based and the absence of any prospect of continuous or satisfactory returns have led in many places to a lack of confidence and to the abandonment of attempts to bring peat-land areas to a profit-yielding basis.

On the continent of Europe much effort is now devoted to encouraging the development of distinct classes of peat land. Good and

relatively poor peat areas are reclaimed at much less cost than was formerly the experience. It is principally through the detailed collation of information for many years past, regarding the formation, structure, and distribution of different kinds of peat deposits, and the botanical, physical, and chemical differences of the various types of their organic contents, as well as through the systematically conducted observations of the several field conditions to be considered, that a corresponding profitable and varied development in the use of these resources has been possible.

More and more in this country the demand is becoming urgent for information concerning peat materials which affect the productiveness and health of crops. Information is called for in estimating the value, the supply, and the possible range of usefulness of special grades of peat for specific crops or for manufactures, for that yielding a satisfactory material as a carrier for bacterial organisms, for fertilizer purposes, for litter, fuel, or distillation products, and for other uses. Advice is needed to point out the difficulties to be avoided, especially when an area of peat land may be developed for both agricultural and technical purposes by communities or associations and may be made increasingly profitable because of the equal, if not greater, value of the underlying mineral soil for staple crops, for special forms of economic plants, or for intensified methods of farming.

There are many instances of failure of efforts based on impractical and previously discarded ideas which time and again have been tried on an extensive scale in Europe and in this country, only to meet the same experience. The traditional disregard for facts of a qualifying nature, or for drawing a plan having due regard for the existing factors and needs of an undertaking; the inability of scientific workers to understand or to compare critically each other's researches in the field of peat investigations, because the terms peat and muck are not qualified and because faulty conceptions regarding them have still an unchallenged place in the scientific literature of this country—these are some of the results of the present situation, and for both national and economic reasons they reflect indeed a serious condition.

Types of peat material, their differences in botanical composition, in disintegration capacity, and in related physical and chemical characteristics have been established in Europe by many years of experience and scientific investigation. They form an adequate basis in problems which deal with methods to be practiced in the development and cultural preparation of a peat deposit, such as the well-known "Veenkultur," the Rimpau cultural method, the German high-moor method, and others, or in operations where the removal of peat for technical uses and centralized power plants is practicable. Data such as those just mentioned, regarding the nature and

behavior of the various types of disintegrating plant remains making up a peat deposit, are considered of special importance in drainage projects intended to be practicable from an engineering and agricultural standpoint; they are essential for an adequate method of dewatering peat materials that are found to be of value for manufacturing purposes. It is rather in the knowledge of the different kinds of peat material, the factors in the field which brought about their accumulation and determined their character, that a satisfactory basis has been found for the improvement of peat by means of suitable crops or by specific operations in the technical industries.

Few phases of botanical inquiry have received as much attention as the development and formation of peat deposits; yet information concerning them appears to be little known and still less considered in practice, though the classical investigations of Andersson (1),[1] Clements (4), Graebner (12), Lesquereux (16), Lorenz (17), Potonié (19), Sendtner (21), Sitenský (22), and especially the works of Früh and Schröter (10), Grisebach (13), Steenstrup (4), Vaupell (23), and Weber (25) are not only comprehensive but fundamental in problems relating to the structure and content of peat deposits.

The attempt to establish a correlation between vegetation and any one factor of the environment is difficult, and though not all field work is of a nature adapted to throw light on this vexed question it has, nevertheless, been possible to make such a correlation in the lines of physical and chemical studies with types of peat material distinct in botanical composition and in degree of disintegration. Practically all the work is thus far European, and the leading investigations, notably those of Bersch (2), Birk (3), Feilitzin (9), Gully (14), Hoering (15), Minssen (18), Virchow (24), and Zailer and Wilk (26–27), follow for the most part modern botanical viewpoints and definitions.

The botanical, physical, and chemical nature of the different peat materials is of the widest practical importance, since it is in general more difficult to change the nature of the vegetable mass than to remedy its deficiencies, but almost equally important is the character of the mineral soil underlying the plant remains. The geological relations have their most important significance in the fact that decaying organic matter and carbonated water have a relatively high solvent action on the minerals of soils and rocks. This effect increases with the area covered by the accumulating masses of peat materials and especially with thicknesses in which oxidizing conditions are absent. Underlying and marginal soils derived from sedimentary, metamorphic, and eruptive rocks, both basic and acid, correspondingly affect the content and quality of peat materials in

[1] The serial numbers in parentheses refer to "Literature cited" at the end of this bulletin.

saline impurities and in acid, alkaline, or neutral reaction. Some of these rock formations yield marked amounts of soluble injurious salts.

Special climatic conditions influence appreciably the disintegration of peat materials, the formation of organic colloidal débris, and the direction of movement or transport of dissolved mineral constituents (8). The reactions may lower the supply and concentration of nearly all available essential plant-food constituents and thus effect malnutrition, a prevalence of plant diseases, and allow certain plants and microorganisms to outgrow others, or they may lead to local accumulations of salts at the surface of the peat deposit or at the margins and in the mineral substratum underneath peat accumulations. Cultural practices and drainage systems in no small measure may favor and accentuate both the contamination through the movement of underground waters or springs in peat materials with high decay capacity and the concentration of salts by seepage or by evaporation. More consequential still are the effects of a pronounced inland or a typical oceanic climate on the disintegration, absorption, deposition, and leaching phenomena. Aside from the presence of either an abundance or a deficiency of agriculturally desirable mineral constituents, the climatic contrasts give rise to classes of peat land which resemble closely the "Tschernosem" and the "Podsol" condition featured by foreign writers (11).

It is obvious, therefore, that those inquiries are likely to be most fruitful which are concentrated first of all on the fundamental problem of determining and characterizing the types of peat material which are representative of distinct regional divisions or geographic areas of the United States and reserve for later discussion the details of the structure and contents of special peat deposits which are considered to be either with or without great value or are selected as representative peat deposits for specific experimental or industrial purposes.

It seems to the writer eminently desirable at this time to give consideration especially to those chief types of peat material in this country which are characteristic of peat deposits in European countries; to emphasize mainly the grades or types which resemble or coincide with each other and whose botanical composition is based upon the remains of plants known to occur in Europe; and to characterize those phases which are preserved conspicuously in a similar stage of disintegration in this country, irrespective of their positional relationship in the different layers of a peat deposit. They alone demand consideration in the present state of our imperfect knowledge, partly because through the recognition of these types considerable progress can be made in the fixing of standards of quality and in securing their adoption; largely, however, because the physical and chemical characteristics of these types have been sys-

tematically worked out by European scientists and their investigations contain a number of important contributions which are of value for several lines of work in peat utilization.

In this country the character of several of the peat materials of both fresh-water and salt-water origin differs in various respects from that of the European Continent. This difference would probably necessitate a special grouping and series of standards. Under the varying conditions of environment existing over the great regions of the United States in which peat materials may be found, the resulting types and their relative values must, obviously, vary quite as much on account of the distribution of peat-forming vegetation and the effects of the regional geological conditions and climate as on account of the local topography or the nature and position of the ground water in and upon which the plant remains are accumulating. So far, however, as the characterization is based upon differences of botanical composition rather than the stratigraphic series or upon differences in the vegetational surface cover or regional or local modifying field influences, the lines of demarcation are simple and sharp. The general recognition of the botanical composition of peat materials would initiate a movement in the direction of effective use of specific peat-land areas, and it might bring about a more satisfactory coordination of scientific activities. There is little doubt that on some such basis as this a closer union of the several lines of research and farm practices would be mutually beneficial and scientifically as well as agriculturally and economically profitable.

How much there is need for information of this kind may well be illustrated by consideration of the following facts. In many instances projects of drainage and reclamation which appeared feasible from an engineering standpoint have proved unprofitable as an agricultural investment, mainly through the scant consideration of adequate agricultural criteria which would render the work advisable or the project economically sound. In most cases the result proved unsatisfactory through lack of information concerning the merits and adaptability of the peat materials and the nature of the field conditions limiting their possibilities. It is easily ascertained whether a deposit may be drained to the bottom or only through the deepening of the outlet channel or by diking and pumping. But the nature of the plant remains, their disintegration capacity and resistance to weathering, the amount of shrinkage to be anticipated, the influence upon them of marginal mineral soils, springs, and ground waters, the features which might impair the value of the mineral subsoil for future agricultural uses—these are not so readily determined. Too much care can not be taken in the preliminary examination of peat land before proposing improvements. Through ad-

visory measures it is possible to forestall mistaken effort, to weed out undesirable enterprises, to select such deposits as can profitably be left as permanent "water-storing" reservoirs, preserved in their natural condition, and to assist individual or cooperative attempts in maintaining in an efficient manner those projects which are approved by agricultural merit, by economic need, by favorable markets and transportation facilities, or by the promotion of public health.

On many of the peat deposits which are peculiar in their type of material, in acidity, or in salt content, imitation of practice has led to their use for crops grown in succession at the expense of other agricultural industries, such as tillage farming combined with pasture, live-stock, or dairy farming, which would have been more suitable and would more regularly produce profitable returns. It is to be regretted that practically no extensive use has been made of the grasses, cereals, and fruit trees which are suitable for peat-land types and could be profitably developed. The natural extension of crops possible on peat areas is deserving of more systematic attempts, because it will be necessary to devote unusual attention in the near future to protect reclaimed deposits of peat now under cultivation against preventable difficulties. The more advanced agriculture becomes, the more diversified are its crop activities and the less will be the risk which attends concentration in a single field of cropping activity. Any work with the view of determining what methods of diversified agriculture are best adapted to and would benefit a certain locality or region, whether carried on by private individuals, communities, scientific institutions, or manufacturing interests, would prevent a great deal of loss to the owners of peat land and others uninformed of the limitations of different classes of peat deposits and their materials.

With the greater interest in live-stock production, the value of many abandoned peat areas as potential beef or cattle producing lands will probably again become enhanced, and it will be necessary to devote more attention than has been given to mixtures of grasses best suited to the several types of peat material or to their drainage capacity. The fact is not to be obscured that the war-time readjustments, aside from labor problems and the demands upon transportation, will tend to increase rather than lessen the need to convert forage and other crops into higher priced finished products.

Another urgent necessity is the extension of desirable peat-land areas for staple crops, notably certain cereals, if the land is annually to turn in its share and render its adequate service to the country and to the farmer. Special varieties of cereals, such as oats, rye, barley, and even wheat, are grown with success on northern European peat lands; their adoption in this country would contribute greatly

not only to increased production, but also to the larger range of crop plants which is so essential to a sound and secure foundation of peat-land agriculture.

In European countries the cultivation of the better grade of cereals is carried on upon peat deposits covered with a layer of sand (the "Cunrau" or "Rimpau" method, in vogue since 1862) and upon peat areas from which most of the organic material has been removed. The practicability of combining the agricultural and commercial utilization of a peat deposit for the production of fuel and food is no longer a questionable procedure. The problem has been well solved in Holland, where certain types of material are removed partly on account of their value for manufacturing purposes; largely, however, because the mineral subsoil has an equally, if not greater, value for the production of garden truck and for staple crops. Of the two methods of developing peat land the practice of sanding peat deposits has not always proved satisfactory. European experience seems to show that the amount of injury from diseases is very small compared with losses in yield from causes due to the selection of peat areas which contained plant remains with an unfavorable decay capacity or in which there appeared in the sand cover, as time went on, relatively injurious compounds from the underlying poorly aerated organic and mineral subsoils. It is, indeed, not unlikely that similar conditions are the cause of the greatly lessened yield in the cranberry crop and other plant industries reported from some deposits in this country.

For reasons such as these, the writer feels justified in the opinion that a preliminary-survey method based upon qualitative as well as quantitative differences of peat materials, which determines their serial position in the profile structure of a deposit and their depth relation and condition of disintegration and which examines the character of the underlying mineral substratum and the nature of its ground water, would offer data which might be of general interest to various lines of peat utilization and would permit an estimate of the probable difficulties or tendencies making for failure. It would prove a more reliable means of arriving at the practical value of peat lands for an undertaking that faces agricultural or industrial utilization, or a combination of both, and it would avoid the discrediting of interests which desire to utilize peat materials for technical and commercial purposes, for bacterial inoculation, as a filler with other fertilizer substances, as a stock-feed ingredient, as fiber, and in other specific ways. It has been the experience in Europe, and undoubtedly in this country as well, that, no matter how excellent the results for a time, certain field conditions qualify the manner and methods of utilization, while the use of some types of peat material introduces sources of failure. Prudence is the more

necessary in the present instance because the characterization of any native local or regional types of peat material has not as yet been coupled with definite or even preliminary botanical, physical, bacteriological, or chemical studies. This is, indeed, a cause for regret, as it is felt that a more comprehensive understanding of important types of this material, if made accessible to workers in different lines of peat utilization, might bring about a more complete coordination of their activities. Mere imitation and undue duplication of effort would be removed through an intelligent conception by each of the connection between the character of the peat deposits, their diverse materials, their value, and the uses most likely to prove successful.

## DEFINITIONS AND POINTS OF VIEW IN CLASSIFYING PEAT MATERIALS.

In an endeavor to classify in some degree the results obtained in the field, a complete understanding is possible only by the consideration of various viewpoints and the meaning of the terms used. Naturally, when attempting a characterization and the grouping into classes of peat deposits and types of their material, it is desirable first to formulate clearly the fundamental lines of work along which this problem may be approached.

This consideration is important, since any controlling condition, whether relating to peat-forming vegetation units and their present distribution, to the character of initial stages of a vegetation series and the corresponding mode of accumulation of peat materials, or to the degree of disintegration and contamination of plant remains, very often compels the formation of a tentative basis upon which systematic observations may be secured. The nature of the results will depend, therefore, much on the question whether the variant plant material or the modifying, controlling, and differentiating factor of field conditions is to serve as the basis for a full characterization. Should the emphasis be placed upon the product or upon the formative process? Would the water table which controls the accumulation of peat and thus gives rise, among other distinctions, to water-formed and land-formed types of material or would differences due to the botanical composition and the sequence of vegetation units forming peat give a more satisfactory working method? Are the quality and value of materials to be determined from the vertical series or profile structure of peat deposits or from climatic and geologic features?

Two clearly related but analytically separable propositions seem to stand out as the essential premises of future work in this field of investigation. The order in which these propositions are stated is

immaterial; one is as important as the other, for each is correlated with the other. Any attempt toward clarity of terms and statements, any definite determination of criteria for the classification or selection of peat deposits and their materials for agricultural or manufacturing purposes depends upon and includes a twofold qualification: (1) The botanical composition and stage of disintegration of the peat materials in a deposit and (2) the controlling basic factors in field conditions. These constitute an effectual limitation to the degree of success obtainable. The numerous abortive attempts at utilization have invariably followed from neglect of one or the other of these essential qualifying factors. Upon the recognition of these depends whether the farmer and the technician are to work by chance or on scientific lines.

It is not within the scope of this paper to deal with an ecological account of peat-forming vegetation units, of the character of initial stages, or of series of developmental stages arising in an area of a particular region. These have been discussed elsewhere in considerable detail (4; 5, p. 220–262).

The object of these notes is to call attention to the following terms and definitions:

**Peat** is an accumulation of plant remains in various stages of disintegration or maceration, laid down in a definite manner according to imposed modifying field conditions. For statistical purposes and for reasons of common scientific interest the use of the term "peat deposit" should be limited to an accumulation of plant remains of at least 8 to 10 inches (20 to 25 centimeters) in thickness when compact and well shrunk. In this accumulation the surface layer of living native vegetation or deposits containing more than 40 per cent of mineral matter must not be included.

**Muck** is a phase of surface peat material which occurs under topographic conditions permitting extensive weathering and the accumulation of large amounts of silt and clay.

**Humus.**—No definition can be given at present, since the well-known defects in the usual methods of humus determination have made it clear that the use of the term in its present meaning is not advisable either in statements relating to soils or fertilizers.

**Marsh (fen), bog, heath, and swamp** are terms used largely on account of the well-marked physiognomy of vegetation which they represent and because they are common names in many languages. The plant remains of each group accumulating as peat are among the most distinctive of peat materials, and the field conditions of each have a more or less differentiating character. The deposits are quite variable in origin and structure, but their structure is primarily dependent on the form of the land surface on which they are found and upon the height of the water table while they are formed. They are dealt with later.

The words "marsh" and "swamp," on the one hand, and "bog" and "heath," on the other, correspond in a very general way with the terms "Flachmoor" and "Hochmoor" used by most European writers. The line of distinction and the transition between them is, of course, nothing like as sharp as the terms would seem to indicate except in regions having climatic conditions where they reach their best development. "Hochmoor" is applied, as a rule, to a class of peat land which rises from the edges toward the middle and

thus shows a convex upper surface. "Hochmoor," or "raised bog," develops typically in regions of high humidity or rainfall, partly on account of the habit of growth of the sphagnum mosses, which form the main component of the surface vegetation cover. "Flachmoor" represents a class of peat land with a flat or even a slightly concave surface. Often a distinction is made on the basis of chemical differences, especially the absence or presence of lime or of acid reaction, but this distinction is not exact.

**Acidity** may arise in various ways and it may persist only for short periods of time. A temporary condition of acidity is common to surface peat materials with insufficient aeration, weathering, or disintegration, due to the presence of carbon dioxid. It should be stated, however, that different peat materials may have different acidities, and much of the soil acidity may be potential rather than active. In bog types of peat, for example, acidity appears to be due partly to the absorbing capacity of the organic materials for bases, breaking up salts and liberating acids (14), and partly to the presence of end products of disintegration which are colloidal substances of an acid character. The activity of microorganisms and certain forms of fungi as acid builders in peat soils and the degree of activity and probable harmfulness have barely been touched by investigators (5). In the marsh types of peat, acidity is caused more frequently by the oxidation of sulphids in the underlying mineral soils or by drainage waters which have become acid through a variety of causes. In a few cases acidity is due to the long-continued application of artificial fertilizers, such as ammonium sulphate and others, that have been used on the soils too heavily. Although the cause of soil acidity and its direct or indirect effects on plants and on the physical, chemical, and biological conditions and processes of soils have been the subject of numerous investigations, any broad statement is unsafe at this time.

From the standpoint of the conditions of accumulation it is desirable to distinguish between transported peat materials, i. e., the group of peat types which were formed in open water and below the water level (the aquatic or allochthonous types of peat), and those which resulted from the preservation of plant remains on the spot actually occupied by the peat-forming vegetation units, the groups of peat material formed at and above the water level (the marsh, swamp, and bog, or autochthonous types of peat).

**The group division** represents the members of a linear genetic sequence or vegetation series which have the same general range of controlling field conditions, e. g., the positions of the ground-water level in relation to the surface. Regional divisions have not been taken into account at present, since they represent the broader relations of types of peat material and the marked differences which are associated with the geographic distribution of vegetation forming peat, with climate, geology, and physiographic relations.

**A type of peat material** is the individual member of a group and is based upon differences in origin, texture, color, etc., and in botanical composition of such plant remains as characterize the organic material most conspicuously.

**Phases** are differences in a type of peat not sufficiently well marked to justify a new subdivision; they are variations in composition of plant remains, in mineral matter, etc., and are in some respects correlative features of certain field conditions.

From the standpoint of the vegetation units forming peat, the layers of plant remains preserved more or less intact are much the more important. They furnish a record of the development and structure of peat deposits, and they represent a more or less definite

series of different vegetation stages, each initiated, continuing, or terminated and replaced in response to changes of basic past and present modifying factors or field conditions. They indicate that of the many plants which occupied the area as an association, only the few forms or species that were dominant and of rather wide geographic distribution contributed to the formation of peat layers.

The course of the development of a peat deposit may have been complete or interrupted, complicated or recurring, according to the conditions which prevailed; the resulting layers of peat material are certain to be correspondingly continuous or fragmentary and isolated. Wherever peat deposits arise, whether in the conversion of wet flat-land surfaces or of basins and kettle holes, on uplands, along river channels, or at the coast, the essential nature of the process is readily established by a comparison of the serial and contemporaneous strata of a deposit. The record is indicated by the profile structure and can be ascertained and reconstructed only by actually probing the layers of plant remains and examining microscopically the more disintegrated materials.

The stratification of a deposit points therefore to changed life relations for the plants which formed peat; to disturbances which ensued through altered conditions of rainfall, of soil moisture and its content of mineral salts, or in the relation of precipitation to evaporation. Unfavorable topographic or soil conditions may even arrest the succession of vegetation and keep it stationary at a point far short of the possible development within the area, but significant is the fact that with further accumulation of plant remains the influence of local vegetational or topographic conditions becomes less marked, while that of the region or climate gradually increases in effectiveness. It is probably for this reason that the older or lower layers of peat deposits of the Scandinavian countries, of Holland, Germany, Austria, Switzerland, Finland, and Russia appear to have a surprising number of features in common with many of the peat deposits of the northern portion of the United States.

There is the possibility of using the present native vegetation together with plants characteristic of corresponding types of peat material as an indicator and criterion of conditions which may serve for a basis of estimating the agricultural and other possibilities of a peat deposit, provided the relation between the surface vegetation cover, the character of the profile structure, and the nature of the field conditions of the deposit is correctly interpreted. It is necessary to bear in mind, however, that by itself the surface vegetation of any unstable stage in the devedopment of peat deposits can not be regarded as being wholly significant in the determination of the latent possibilities of a peat-land area. Much more importance, especially from the standpoint of interests combining agricultural

and technical utilization, should therefore be attached to the profile structure of a peat deposit and to the climatic and geologic differences of peat-land areas.

The arrangement of types and groups of peat material given below is, it should be repeated, a tentative one. It is presented partly from an ecologic point of view and deals, therefore, with a series of peat-forming vegetation units within a set of field conditions such as the writer has described elsewhere for Ohio (5) and Massachusetts (7).

The outstanding physical relationship is the water content of the initial area and its effect upon the character of the series of vegetation stages forming peat and upon the manner of accumulation of plant remains. This fact is of the greatest importance also from an economic point of view in connection with the improvements to be given a peat-land area. It may be accepted as an axiom that undrained deposits of peat contain about 70 to 95 per cent of water, which should not be reduced to less than 65 per cent if the area is to be used for agricultural crops. Drainage and desiccation of peat materials below 60 per cent of water content have been observed to decrease their capacity for disintegration and weathering. The fibrous organic material becomes brittle, inert, maintains its initial appearance for considerable periods of time, and does not become readily nitrified. Certain of the macerated and water-formed types of peat become hard and compact and are not easily penetrated by the roots of crop plants or by water and air. On the other hand, the dewatering of peat materials, especially the macerated types and the well-disintegrated phases of other types, to a water content of approximately 25 to 30 per cent is an essential requirement before they can be used for technical purposes. Desiccation is one of the outstanding problems in connection with the manufacture of peat into a finished product. Thus far, the employment of pressure or of drying other than by the natural action of sun, air, and wind has not proved economically feasible.

It is obvious, therefore, that the utilization of peat deposits for agriculture, for manufacturing purposes, or for a combination of both implies operations which appear in some degree antagonistic. They have been harmonized, however, but only through investigations which give information concerning the quality and quantity of peat materials, the conditions of their formation, and the methods of development required before they can be made available sources of food, power, or finished products. On the continent of Europe industries which are dependent on peat materials for these purposes have been centralized and located in the vicinity of selected deposits situated conveniently with respect to cheap water transportation. Provision is made for contemporaneous and subsequent cultivation

with crops for the purpose of operating the peat deposits at their maximum efficiency. Lack of knowledge of the efforts made along these lines by European workers over a period of more than a century is directly responsible for the failure which the attempts in this country have met.

## A TENTATIVE CLASSIFICATION OF IMPORTANT TYPES OF PEAT MATERIALS.

In the following classification of peat materials all those data of a physical and chemical nature resulting from investigations of European types of peat have been summarized in Tables I and II which, in the opinion of the writer, may safely be applied to the corresponding types of plant remains found to occur in the peat deposits of the Lake belt, e. g., Ohio (5) and the New England States, e. g., Massachusetts (7), and present also in other States within the glaciated area of North America. For purposes of microscopic identification of plant remains the illustrations given in Früh and Schröter (10) afford an excellent basis for analysis and comparison.

### THE AQUATIC GROUP OF PEAT MATERIALS.

Types of peat material (allochthonous) from open water and from shore stages of a vegetation series, of which the plant remains accumulated below the water level.

The peat materials are structureless or coarsely macerated, soft, or compact and sticky, especially in older and deeper strata. They vary in composition, texture, color, etc., according to the depth of water and the character of the water in the initial stages of the area or of the vegetation series; they are largely, though not wholly, composed of the more resistant residues of plant remains, bits of woody and fibrous material, fragments of root and shoot tissue, the outer coats of cellular organisms, and a finely macerated débris as an embedding or binding ground mass which has either partly or wholly lost all vestige of its original organic structure. To this is added in various proportions and from various sources material of plant and animal origin, as well as dust, silt, etc., from the surrounding area, laid down by wind and current.

Several distinct vegetation units which grow either free floating, wholly submerged, or rooted and partly submerged in water may form at any level considerable and extensive layers of material by the constant accretion of plant remains. These peat-forming plants are represented to-day by a great number of species and individuals with semiaquatic habits of growth in fresh and brackish water. Among them are species of Ceratophyllum, Potamogeton, Castalia, Nymphaea, Peltandra, Pontederia, Polygonum, Decodon,

and to a smaller extent Typha, Phragmites, and other genera more typical of the later grass and sedge vegetation units. The maximum depth at which a number of the water plants and semi-aquatics can grow and accumulate as peat in situ varies with the clearness and temperature of the water, but it rarely exceeds 15 feet (5 meters) below the surface of the water level. Under conditions which accelerate the disintegration of organic material, as in regions having a moderate winter season or which give rise to ground water colored brown from the presence of suspended and dissolved organic débris, the filling of depressions is chiefly from the bordering marsh, bog, or swamp vegetation units.

Three clearly distinguishable types of peat derived from this vegetation are encountered frequently in the same deposit, which differ from one another throughout in texture, color, composition, shrinkage, and other characteristics. In some deposits, however, these distinctions intergrade or the material occurs wedged in as a ground mass among the interstices of woody or fibrous types of peat, or it may be wholly absent.

The peat mass composed of very small particles possesses many of the properties of a colloid and is on that account of the greatest importance in the problem of dewatering the material for the growth of crops or for manufacturing purposes. It is difficult to remove the water content to below 80 per cent, and when dry these types of peat may form gaping cracks and may shrink to one-fourth and even to one-eleventh of their original profile dimension. They are easily tilled, but under cultivation in open crops readily become finely granular, forming a dustlike powder, almost impervious to water, probably caused by the absorption of air. Loss in yields from wind erosion and plant diseases appears to be a detracting feature in this group unless provision is made for windbreaks, irrigation, or for a cropping system that combines or alternates with grasses, small cereals, and broad-leaved crops. The use of sand by mixing it or by covering the peat material with a layer of sand 6 to 8 inches (15 to 20 cm.) thick should be practiced with caution; the method increases in most cases the yield as well as the possibility for growing a greater variety of crops, including truck, cereals, and other staple crops, but losses have been reported due to the selection of unfavorable deposits of material.

Some of the materials are noteworthy because of the relatively high nitrogen content, while others contain more of the waxy, resinous, and other ether and alcohol soluble organic débris (see Table I) from shrubby or herbaceous evergreens. On account of the greater resistance to oxidizing and other agents and to bacterial action, this plant residue disintegrates slowly and tends to accumulate in con-

siderable thicknesses. The high content of organically combined nitrogenous substances is mainly related to the botanical composition of the plant remains and their slow disintegration capacity. They are largely of protein origin, but partly chitinous, "coprogenous," in nature, being skeletal portions and egg cases of insect and other animal life, and to some extent derived from spores and mycelial components. They are extremely resistant to decomposition. A high content of nitrogenous peat substances should not be looked upon necessarily as an important factor in judging the manurial or soil value of peat and muck. Materials from other types of plant remains, though exhibiting smaller values of resistant organic nitrogen, offer greater possibilities for meeting the agricultural and other requirements for soluble nitrogen.

Features such as those described above, especially regarding the ether and alcohol soluble component, make the material valuable for fuel as peat powder or as machine peat in the form of air-dried brick-shaped blocks and for coking or distillation products, provided the ash content is low. They are relatively less desirable for agricultural purposes or for use in gas generators on account of the presence of the resistant components and pitch-yielding and soot-forming by-products.

Frequently the material shows a mottled coloring on account of the presence of sulphur accumulating either in a finely divided form, as small nodules, as crystals of iron and lime compounds, or in organic combination. Ferruginous inclusions are likely to be unavailable or injurious when available; they generally add some shade of red or yellow to the peat material when air dry, or, more rarely, the bluish tint of the phosphatic iron compound "vivianite" (blue iron earth). Contaminations of that kind in fields not suitably drained retard considerably the growth of crops unless the peat material is well aerated, underdrained, limed, or supplied with finely ground rock phosphate and potash-bearing minerals. As mud baths, the saline phases of these types are reported to have proved medicinally valuable, and in European countries they have become the centers of health resorts.

### MACERATED TYPE.
### "Mudde," "Sapropel," "Gyttja."

Reddish brown to deep brown, more or less macerated plant remains with a fine-grained, oozelike plastic to sticky ground mass in various proportions, which occurs as a filler or binding material in the interstices between the less easily destructible fragments of plant tissue. The material is derived indiscriminately from vegetation units bordering open water. Some of the original identity and form is retained in spores, pollen grains, seeds, leafy and other frag-

ments of pondweed material, bits of smooth and pustulate rootlets, and in the coarser woody, cuticular, or other resistant components. Animal derivatives, such as chitinized skeletal portions and egg cases from insects, are frequent.

The data in Table I are intended to show the marked differences which may result from the presence of ether and alcohol soluble substances, nitrogenous compounds, and products valued in the distillation of peat.

Seasonal admixtures of clay, silt, and sand produce, as a rule, thinly laminated gritty layers, with cleavage planes which often contain leafy impressions, small stems, and other drifted material. The variations in mineral matter constitute phases of the type when the relative proportion, e. g., of iron, sand, silt, or clay, is above 40 per cent.

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TABLE I.—*Chemical characteristics of important types of peat material.*

[The data given show the constituents of 100 parts of material, all being on the moisture-free basis except as noted. Abbreviations ("Authority" column), giving credit for data: B=Birk (3), M=Minssen (18), Z=Zailer and Wilk (26-27).]

| Types. | Authority. | Organic matter. | Mineral matter (ash). | $SiO_2$ and insoluble. | N. | $P_2O_5$. | $K_2O$. | CaO. | $Fe_2O_3+Al_2O_3$. | $SO_3$. | Extract. | | | Elementary analysis. | | | | Coke (charcoal). | Tar and tar water. | Gas. | Calories. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Ether soluble. | Alcohol soluble. | Total. | C. | H. | O. | N. | | | | |
| *Sec. A.*—Aquatic group: | | | | | | | | | | | | | | | | | | | | | |
| 1. Macerated type— | | | | | | | | | | | | | | | | | | | | | |
| Level not indicated | M. 72. | 59.20 | 40.80 | 32.26 | 2.48 | | | 2.34 | | | 0.93 | 3.00 | a3.93 | | | | | | | | 3,249 |
| | M. 25. | 93.81 | 6.19 | 4.13 | .86 | 0.03 | 0.01 | .46 | 0.82 | 0.54 | 15.62 | 27.89 | a43.51 | | | | | | | | 6,839 |
| | M. 26. | 48.53 | 51.47 | 45.51 | .69 | .06 | .16 | .25 | 4.82 | .30 | 5.29 | 10.88 | 16.17 | | | | | | | | 3,371 |
| 0 to 0.60 m. level | M. 108 | a15.22 | 84.78 | 76.84 | .73 | | | .40 | | | .50 | 3.20 | a3.70 | | | | | b64.20 | b25.50 | b10.3 | |
| 2.10 to 3.55 m. level | B. 46. | a93.57 | 6.43 | | 1.70 | | | | | .48 | 4.24 | 11.95 | a16.19 | 61.29 | 5.55 | 24.55 | 1.70 | c40.66 | d59.34 | | 5,540 |
| 3.40 to 3.90 m. level | B. 33. | a74.64 | 25.36 | | 1.02 | | | | | | | | | | | | | c36.50 | d63.50 | | 4,703 |
| 5 to 5.65 m. level | B. 26. | a22.74 | 77.26 | | .46 | | | | | .40 | .86 | 2.14 | a3.00 | 12.94 | .95 | 7.99 | .46 | c51.28 | d48.72 | | 1,102 |
| 2. Colloidal type— | | | | | | | | | | | | | | | | | | | | | |
| Level not indicated | Z. | 96.44 | 3.56 | .10 | 1.03 | .04 | .04 | 2.85 | .18 | .22 | 2.24 | 2.85 | 5.09 | 55.17 | 5.11 | 35.13 | 1.03 | | | | 4,934 |
| | Z. | 71.71 | 28.29 | | 2.80 | | | | | | 1.57 | 3.49 | 5.06 | 41.87 | 6.03 | 21.01 | 2.80 | | | | 4,170 |
| | M. 27. | 70.96 | 29.04 | 20.44 | 3.68 | .28 | .13 | 4.58 | 1.98 | 1.24 | .76 | 3.93 | a4.69 | | | | | | | | 3,846 |
| 20 to 120 cm. level | M. 88. | a46.46 | 53.54 | 49.37 | .94 | | | .35 | | | 2.91 | 5.89 | a8.79 | | | | | b68.10 | b20.0 | b11.9 | 2,583 |
| 0 to 40 cm. level | M. 95. | a43.96 | 56.04 | 3.75 | 1.98 | | | 30.23 | | | 1.13 | 2.91 | a4.04 | | | | | | | | 2,886 |
| 40 to 100 cm. level | M. 96. | a48.06 | 51.94 | 6.92 | 2.14 | | | 26.94 | | | 1.21 | 3.34 | a4.55 | | | | | | | | 2,099 |
| 3. Doppleritic type— | | | | | | | | | | | | | | | | | | | | | |
| Level not indicated | Z. 1. | 96.01 | 3.99 | | .96 | | | | | | .49 | .85 | 1.34 | 53.14 | 3.96 | 37.95 | .96 | | | | 4,881 |
| | Z. 2. | 94.56 | 5.44 | .44 | .92 | .03 | .04 | 3.89 | .35 | .23 | | | | 51.71 | 3.77 | 38.16 | .92 | | | | 4,686 |
| *Sec. B.*—Marsh group: | | | | | | | | | | | | | | | | | | | | | |
| Phragmites communis | Z. | 95.80 | 4.20 | 1.73 | 1.46 | .16 | .38 | .73 | .33 | .50 | 1.82 | 9.59 | 11.42 | 47.74 | 6.22 | 40.38 | 1.46 | | | | 4,344 |
| 4. Reed-grass type— | | | | | | | | | | | | | | | | | | | | | |
| Fibrous | Z. | 85.35 | 14.65 | 7.51 | 1.86 | .16 | .24 | .94 | 4.17 | 1.18 | .96 | 1.47 | 2.43 | 47.15 | 5.12 | 31.22 | 1.86 | | | | 4,262 |
| Poorly disintegrated | Z. | 88.20 | 11.80 | 5.22 | 2.29 | .16 | .05 | 3.02 | 1.10 | 1.98 | 1.08 | 1.95 | 3.03 | 51.38 | 5.07 | 29.46 | 2.29 | | | | 4,581 |
| Largely disintegrated | Z. | 89.54 | 10.46 | 3.16 | 3.07 | .17 | .03 | 4.99 | .49 | 1.32 | .85 | 1.70 | 2.55 | 52.04 | 4.58 | 29.86 | 3.07 | | | | 4,691 |
| Wholly disintegrated | Z. | 87.15 | 12.85 | 8.49 | 1.88 | .09 | .26 | .45 | 2.57 | .78 | 3.68 | 3.97 | 7.65 | 52.88 | 4.65 | 27.74 | 1.88 | | | | 4,754 |
| 0 to 20 cm. level | M. 18. | 92.29 | 7.71 | 2.94 | 2.65 | .09 | .09 | 2.63 | 1.20 | .56 | 1.61 | 5.65 | a7.26 | | | | | | | | 4,794 |
| 20 to 60 cm. level | M. 19. | 92.71 | 7.29 | .87 | 2.52 | .11 | .06 | 3.86 | 1.12 | 1.09 | 1.27 | 4.40 | a5.67 | | | | | b41.80 | b27.0 | b31.2 | 4,811 |
| Upper layer | M. 70. | a70.91 | 29.09 | 17.14 | 2.37 | | 2.58 | | | | .73 | 2.18 | a2.91 | | | | | b52.50 | b29.7 | b17.8 | 3,658 |
| Lower layer | M. 71. | a57.16 | 42.84 | 28.17 | 1.25 | | 1.40 | | | | .68 | 2.65 | a3.33 | | | | | b56.50 | b27.4 | b16.1 | 2,958 |
| 1.30 to 1.45 m. level | B. 64. | 96.94 | 3.06 | | 1.70 | | | | | | | | | | | | | c33.78 | d66.22 | | |
| Carex stricta | Z. | 93.97 | 6.03 | 1.95 | 1.29 | .46 | 1.75 | .54 | .28 | .36 | 2.09 | 8.76 | 10.85 | 47.79 | 5.76 | 39.13 | 1.29 | | | | 4,173 |
| 5. Sedge type— | | | | | | | | | | | | | | | | | | | | | |
| Fibrous | Z. | 96.16 | 3.84 | .59 | 2.19 | .06 | .06 | 1.77 | .42 | .76 | 2.27 | 2.70 | 4.97 | 54.58 | 5.56 | 33.83 | 2.19 | | | | 4,993 |
| Poorly disintegrated | Z. | 96.03 | 3.97 | 1.56 | 1.63 | .07 | .04 | .50 | 1.40 | .28 | 2.96 | 7.13 | 10.09 | 58.55 | 5.71 | 30.14 | 1.63 | | | | 5,226 |
| Largely disintegrated | Z. | 96.49 | 3.51 | .29 | 2.10 | .05 | .04 | 1.52 | .99 | .46 | 2.94 | 4.79 | 7.73 | 58.21 | 5.21 | 30.97 | 2.10 | | | | 5,256 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wholly disintegrated | Z | 94.32 | 5.68 | 1.09 | 1.32 | .04 | .03 | 2.53 | 1.47 | .28 | 6.25 | 5.02 | 11.27 | 58.25 | 5.63 | 29.13 | 1.32 | | | 5,314 |
| Level not indicated | M. 46 | a94.12 | 5.88 | 1.61 | 3.07 | | | 1.35 | | | 2.58 | 6.44 | a9.02 | | | | | | | 5,212 |
| | M. 47 | a94.88 | 5.12 | .28 | 2.75 | | | 2.73 | | | 2.43 | 6.35 | a8.78 | | | | | | | 5,235 |
| | M. 66 | a79.14 | 20.86 | 11.77 | 2.22 | | | 1.36 | | | 1.51 | a4.10 | a5.61 | | | | | | | 4,055 |
| Upper layer | M. 10 | 93.88 | 6.12 | 1.37 | 2.94 | .20 | .06 | 2.75 | 1.12 | .39 | 1.03 | 3.58 | a4.61 | | | | b60.60 | b33.7 | b5.7 | 5,352 |
| Lower layer | M. 11 | 95.26 | 4.74 | .40 | 2.47 | .14 | .05 | 2.60 | .80 | .45 | 1.57 | 4.53 | a6.10 | | | | b36.90 | b38.8 | b24.3 | 5,387 |
| Hypnum mosses— | | | | | | | | | | | | | | | | | | | | |
| H. sarmentosum | Z | 97.19 | 2.81 | .95 | 1.39 | .13 | .19 | .52 | .32 | .43 | 1.73 | 2.96 | 4.69 | 50.71 | 4.66 | 40.49 | 1.39 | | | 4,477 |
| H. trifarium | Z | 93.84 | 6.16 | 2.30 | 1.23 | .42 | .28 | 1.43 | .69 | .30 | 1.21 | 7.44 | 8.65 | 45.98 | 5.62 | 41.01 | 1.23 | | | 4,157 |
| H. scorpioides | Z | 94.13 | 5.87 | 2.64 | 1.18 | .24 | .39 | 1.15 | .60 | .26 | 1.48 | 6.95 | 8.43 | 46.30 | 5.63 | 41.02 | 1.18 | | | 4,194 |
| 6. Brown-moss type— | | | | | | | | | | | | | | | | | | | | |
| Fibrous | Z | 92.39 | 7.61 | 1.46 | 2.06 | .07 | .12 | 3.00 | .37 | 2.25 | .94 | 2.24 | 3.18 | 49.73 | 5.27 | 35.33 | 2.06 | | | 4,519 |
| Poorly disintegrated | Z | 94.27 | 5.73 | 2.73 | 2.25 | .08 | .08 | .43 | 1.78 | .42 | 2.37 | 5.04 | 7.41 | 54.82 | 5.79 | 31.41 | 2.25 | | | 4,774 |
| Largely disintegrated | Z | 96.68 | 3.32 | .26 | 2.08 | .05 | .05 | 1.14 | 1.29 | .42 | 2.90 | 4.23 | 7.13 | 56.23 | 6.08 | 32.29 | 2.08 | | | 5,041 |
| *Sec. C.*—Bog group: | | | | | | | | | | | | | | | | | | | | |
| Sphagnum mosses— | | | | | | | | | | | | | | | | | | | | |
| S. acutifolium | Z | 97.58 | 2.42 | .84 | 1.21 | .11 | .39 | .33 | .14 | .26 | 1.27 | 3.87 | 5.14 | 48.23 | 5.33 | 42.81 | 1.21 | | | 4,521 |
| S. cymbifolium | Z | 97.13 | 2.87 | .81 | 1.08 | .10 | .18 | .99 | .15 | .25 | .93 | 2.58 | 3.51 | 48.62 | 5.31 | 42.12 | 1.08 | | | 4,521 |
| 7. Bog-moss type— | | | | | | | | | | | | | | | | | | | | |
| Fibrous | Z | 98.07 | 1.93 | .94 | .89 | .06 | .11 | .28 | .27 | .15 | 1.16 | 2.98 | 4.14 | 48.60 | 5.12 | 43.46 | .89 | | | 4,551 |
| Poorly disintegrated | Z | 99.36 | .64 | .18 | .79 | .05 | .06 | .12 | .07 | .08 | 2.33 | 4.24 | 6.57 | 50.25 | 5.27 | 43.05 | .79 | | | 4,723 |
| Largely disintegrated | Z | 96.79 | 3.21 | .49 | 1.35 | .05 | .05 | 1.78 | .33 | .30 | 4.22 | 5.50 | 9.72 | 55.54 | 5.46 | 34.44 | 1.35 | | | 5,283 |
| Wholly disintegrated | Z | 96.08 | 3.92 | 3.04 | .88 | .04 | .10 | .08 | .44 | .11 | 5.58 | 11.16 | 16.74 | 59.82 | 4.93 | 30.45 | .88 | | | 5,447 |
| 25 to 45 cm. level | M. 3 | 98.19 | 1.81 | .82 | .69 | .03 | .02 | .22 | .20 | .20 | 2.72 | 6.48 | a9.20 | | | | | | | 4,814 |
| 50 to 70 cm. level | M. 4 | 97.85 | 2.15 | 1.17 | .64 | .04 | .03 | .20 | .22 | .18 | 2.26 | 5.62 | a7.88 | | | | | | | 4,706 |
| 0 to 30 cm. level | M. 35 | 96.83 | 3.17 | 1.69 | 1.37 | | | .23 | | | 2.68 | 6.93 | a9.61 | | | | | | | 4,698 |
| 150 to 180 cm. level | M. 40 | a98.14 | 1.86 | .57 | 1.18 | | | .20 | | | 4.02 | 9.15 | a13.17 | | | | | | | 5,104 |
| 270 to 300 cm. level | M. 44 | a98.30 | 1.70 | .30 | 1.32 | | | .27 | | | 6.46 | 12.55 | a19.01 | | | | | | | 5,484 |
| 0 to 2 m. level | B. 22 | a97.40 | 2.60 | | .96 | | | | | .44 | 2.37 | 5.76 | a8.13 | 51.40 | 5.90 | 38.72 | .96 | c31.67 | d68.33 | 4,744 |
| 2 to 3 m. level | B. 23 | a98.41 | 1.59 | | 1.08 | | | | | .36 | 6.02 | 12.72 | a18.74 | 57.05 | 5.49 | 34.32 | 1.08 | c36.03 | d63.97 | 5,455 |
| 0 to 1.2 m. level | B. 42 | a98.44 | 1.56 | | .65 | | | | | .38 | 2.96 | 9.36 | a13.32 | 47.52 | 5.93 | 43.86 | .65 | c31.06 | d68.94 | 4,631 |
| 1.45 to 2.10 m. level | B. 45 | a97.47 | 2.53 | | .84 | | | | | .25 | 5.90 | 19.60 | a25.50 | 55.12 | 5.47 | 35.82 | .84 | c40.86 | d59.32 | 5,485 |
| Scheuchzeria palustris | Z | 95.95 | 4.05 | .40 | 1.85 | .28 | .77 | .88 | .93 | .30 | 1.74 | 6.70 | 8.44 | 49.07 | 5.77 | 39.26 | 1.85 | | | 4,417 |
| 8. Arrow-grass type— | | | | | | | | | | | | | | | | | | | | |
| Poorly disintegrated | Z | 96.20 | 3.80 | 2.19 | 2.62 | .31 | .04 | .24 | .77 | .11 | 3.19 | 4.30 | 7.49 | 54.82 | 5.94 | 32.82 | 2.62 | | | 4,968 |
| Fiber | Z | 97.76 | 2.24 | .49 | 2.15 | .25 | .14 | .33 | .72 | .14 | 3.16 | 3.82 | 6.98 | 55.22 | 6.37 | 34.02 | 2.15 | | | 4,991 |
| Level not indicated | M. 7 | 96.43 | 3.57 | 1.54 | 2.09 | .19 | .07 | .56 | .91 | .16 | 3.48 | 8.96 | a12.44 | | | | b21.30 | b42.5 | b36.2 | 5,034 |
| | M. 48 | a95.64 | 4.36 | .99 | 2.01 | | | 1.80 | | | 4.69 | 8.90 | a13.59 | | | | | | | 5,387 |
| | M. 53 | a96.01 | 3.99 | .54 | 1.77 | | | 1.73 | | | 4.47 | 9.33 | a14.80 | | | | | | | 5,516 |
| 1.25 to 1.45 m. level | B. 59 | a99.03 | .97 | | 1.05 | | | | | | 1.71 | 6.66 | a8.37 | | | | c29.56 | d71.44 | | |
| Eriophorum vaginatum | Z | 98.06 | 1.94 | .41 | 1.31 | .29 | .32 | .27 | .11 | .21 | 1.48 | 4.65 | 6.13 | 49.07 | 5.68 | 42.00 | 1.31 | | | 4,473 |
| 9. Cotton-grass type— | | | | | | | | | | | | | | | | | | | | |
| Poorly disintegrated | Z | 99.41 | .59 | .05 | .85 | .02 | .05 | .11 | .16 | .12 | 4.69 | 8.81 | 13.50 | 58.98 | 5.00 | 34.58 | .85 | | | 5,188 |
| Fiber | Z | 99.47 | .53 | .14 | 1.26 | .04 | .03 | .06 | .13 | .07 | 2.79 | 3.80 | 6.59 | 52.64 | 5.41 | 40.15 | 1.26 | | | 4,906 |
| Level not indicated | M. 49 | a97.02 | 2.98 | 1.32 | 1.33 | | | .54 | | | 5.08 | 10.56 | a15.64 | | | | | | | 5,152 |
| | M. 50 | a95.61 | 4.39 | 1.60 | 1.33 | | | 1.37 | | | 7.41 | 12.88 | a20.39 | | | | | | | 5,236 |
| | M. 51 | a97.50 | 2.50 | .77 | 1.19 | | | .62 | | | 4.90 | 9.84 | a14.74 | | | | | | | 4,974 |
| Calluna vulgaris | Z | 98.88 | 1.12 | .08 | .83 | .06 | .18 | .18 | .23 | .13 | 3.99 | 9.06 | 13.05 | 52.95 | 5.77 | 38.63 | .83 | | | 4,805 |
| Calluna vulgaris, whole plants | M. 32 | 97.13 | 2.87 | .56 | 1.04 | .23 | .51 | .67 | .10 | .23 | 6.60 | 24.72 | a31.32 | | | | | | | 5,295 |
| Vaccinium oxycoccus | Z | 97.70 | 2.30 | | .76 | | | | | | 2.93 | 9.02 | 11.95 | 52.58 | 5.57 | 38.79 | .76 | | | 4,812 |

*a* Data interpolated by the writer. *b* On basis of the air-dry substance. *c* On basis of the combustible substance. *d* Volatile matter.

TABLE I.—*Chemical characteristics of important types of peat material*—Continued.

| Types. | Authority. | Organic matter. | Mineral matter (ash). | $SiO_2$ and insoluble. | N. | $P_2O_5$. | $K_2O$. | CaO. | $Fe_2O_3+Al_2O_3$. | $SO_3$. | Extract. | | | Elementary analysis. | | | | Coke (charcoal). | Tar and tar water. | Gas. | Calories. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Ether soluble. | Alcohol soluble. | Total. | C. | H. | O. | N. | | | | |
| *Sec. C.*—Bog group—Cont'd. | | | | | | | | | | | | | | | | | | | | | |
| Vaccinium oxycoccus, whole plants | M. 129 | 97.37 | 2.63 | 0.07 | 0.91 | ..... | ..... | 0.78 | ..... | ..... | 4.69 | 22.41 | a27.10 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 4,941 |
| Andromeda polifolia | Z..... | 97.09 | 2.91 | ..... | .86 | ..... | ..... | ..... | ..... | ..... | 4.47 | 8.12 | 12.59 | 52.33 | 5.90 | 38.00 | 0.86 | ..... | ..... | ..... | 4,942 |
| Myrica gale | M. 130 | 98.56 | 1.44 | .06 | 1.45 | ..... | ..... | .36 | ..... | ..... | 3.43 | 17.28 | a21.71 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 5,039 |
| 10. Bog-shrub type— | | | | | | | | | | | | | | | | | | | | | |
| Heath peat | Z..... | 89.99 | 10.01 | 7.65 | 2.28 | 0.22 | 0.12 | 0.29 | 1.42 | 0.18 | 2.59 | 6.30 | 8.89 | 51.50 | 5.06 | 30.98 | 2.28 | ..... | ..... | ..... | 4,690 |
| Level not indicated | M. 1.. | 95.25 | 4.75 | 3.29 | 1.21 | .09 | .07 | .22 | .54 | .25 | 3.30 | 9.28 | a12.58 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 4,879 |
| | M. 2.. | 93.69 | 6.31 | 5.02 | 1.45 | .12 | .06 | .14 | .50 | .20 | 2.73 | 7.73 | a10.46 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 4,812 |
| *Sec. D.*—Swamp group: | | | | | | | | | | | | | | | | | | | | | |
| Deciduous shrub types | Z..... | 98.40 | 1.60 | .20 | 1.37 | .04 | .05 | .54 | .34 | .32 | 3.78 | 5.53 | 9.31 | 59.64 | 4.80 | 32.59 | 1.37 | ..... | ..... | ..... | 5,236 |
| 11. Alder type— | | | | | | | | | | | | | | | | | | | | | |
| Surface layer | M. 12. | 92.94 | 7.06 | 1.86 | 1.99 | .10 | .07 | 2.39 | 1.21 | 1.10 | 2.92 | 5.74 | a8.66 | ..... | ..... | ..... | ..... | b42.30 | b31.5 | b26.2 | 5,140 |
| 20 to 60 cm. level | M. 14. | 91.46 | 8.54 | 3.90 | 2.23 | .15 | .06 | 1.77 | 1.87 | .49 | 3.25 | 8.48 | a11.73 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 4,920 |
| 0 to 20 cm. level | M. 15. | 83.20 | 16.80 | 5.61 | 3.19 | .15 | .08 | 6.35 | 2.24 | 2.19 | 2.68 | 6.53 | a9.21 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 4,371 |
| 30 to 60 cm. level | M. 16. | 87.20 | 12.80 | 1.99 | 3.09 | .11 | .08 | 7.39 | 1.31 | 1.64 | 2.97 | 6.95 | a9.92 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 4,700 |
| 3.10 to 3.30 m. level | B. 38. | a80.52 | 19.48 | ..... | 1.31 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | c34.51 | d65.49 | ..... | ..... |
| 12. Birch type— | | | | | | | | | | | | | | | | | | | | | |
| Poorly disintegrated | Z..... | 97.82 | 2.18 | .50 | 1.60 | .05 | .05 | .53 | .43 | .49 | 5.28 | 6.85 | 12.13 | 59.19 | 5.60 | 31.42 | 1.60 | ..... | ..... | ..... | 5,388 |
| Partly disintegrated | Z..... | 96.56 | 3.44 | .68 | 2.29 | .14 | .03 | .39 | 1.76 | .29 | 5.22 | 6.69 | 11.91 | 59.02 | 5.77 | 29.48 | 2.29 | ..... | ..... | ..... | 5,477 |
| Level not indicated | M. 8.. | 97.40 | 2.60 | .50 | 1.16 | .06 | .05 | .59 | .89 | .31 | 3.90 | 9.14 | a13.04 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 5,520 |
| | M. 9.. | 94.57 | 5.43 | 3.15 | 1.57 | .05 | .08 | .45 | .97 | .32 | 6.36 | 12.58 | a18.94 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 5,537 |
| 3.15 to 4.25 m. level | B. 24. | a98.20 | 1.80 | ..... | 1.31 | ..... | ..... | ..... | ..... | .35 | 7.69 | 16.36 | a24.05 | 57.29 | 6.01 | 33.25 | 1.31 | c37.69 | d62.31 | | 6,007 |
| 13. Deciduous-forest types | Z..... | 90.69 | 9.31 | ..... | .90 | ..... | ..... | ..... | ..... | ..... | 5.27 | 3.84 | 9.11 | 52.14 | 4.54 | 33.11 | .90 | ..... | ..... | ..... | 4,734 |
| 3.70 to 4.60 m. level | B. 12. | a38.74 | 61.16 | ..... | .58 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | c44.46 | d55.54 | ..... | ..... |
| 0.80 to 1.50 m. level | B. 73. | a95.52 | 4.48 | ..... | 1.73 | ..... | ..... | ..... | ..... | .39 | 4.12 | 8.75 | a12.97 | ..... | ..... | ..... | ..... | c36.69 | d63.31 | ..... | ..... |
| 14. Coniferous-forest types— | | | | | | | | | | | | | | | | | | | | | |
| 4.60 to 6.35 m. level | B. 9.. | a33.33 | 6.67 | ..... | 1.59 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | c38.19 | d61.81 | ..... | ..... |
| 4.25 to 5 m. level | B. 25. | a98.37 | 1.63 | ..... | .86 | ..... | ..... | ..... | ..... | .35 | 10.76 | 24.22 | 34.98 | 66.15 | 5.93 | 25.25 | .86 | c36.48 | d63.52 | | 6,615 |

a Data interpolated by the writer. b On basis of the air-dry substance. c On basis of the combustible substance. d Volatile matter.

Especially interesting in this connection are the marly and diatomaceous accumulations, which on account of their importance are treated here as subtypes.

*Characeous subtype.*—Structureless, mainly calcareous plant remains, predominantly the deposition of calcium carbonate by green algæ, such as the stoneworts Chara and Nitella; usually comminuted granular fragments, soft, friable, and cream colored to white when pure, yellowish to dark rusty red according to the amount of iron present, grayish brown to black and granular when admixed with herbaceous plant remains.

Shell-marl phases are quite common among various types of peat, but the shell remains from mollusks are not an important factor in the production of the larger or more extensive accumulations of marl. Inclusions, such as calcareous tufa, concretions and nodules caused by blue-green algæ or by bacterial precipitation, and flaky incrustations on semiaquatic plants, mosses, rhizomes of herbaceous plants, and a form of fine tubular material derived from mats of stonewort buried essentially intact, are occasionally found embedded in the macerated types of peat material. Most of the calcareous subtype of plant remains is covered with herbaceous organic matter, but outcrops and layers between beds of peat material are frequent in level valleys.

Extensive deposits of marl and of marly peat materials of other types occur mainly in regions underlain by rock formations containing limestone and in areas where streams, underground and spring waters, or the soil material adjacent to and underneath a peat area are derived from calcareous drift.

Sandy, argillaceous, ferruginous, phosphatic, and peaty marls owe their names to their obvious admixture. Marly phases of peat are as a rule granular, grayish brown to blackish gray in color, and inclined to be high in available nitrogen when under cultivation. To restore a proper balance in the ratio of plant food constituents, they therefore should not be treated with nitrogenous fertilizers. Where the amount of lime is too high, crops tend to become chlorotic and are susceptible to nutritional disturbances.

Beds of pure marl are used in the manufacture of cement, and they furnish lime of value as an agricultural fertilizer.

*Diatomaceous subtype.*—Structureless, mainly siliceous material from plant remains consisting of diatomaceous shells admixed with a varying proportion of sponge spicules, spore cells, macerated or fibrous plant material, and drift débris; light gray in color and compact but of very little weight in proportion to its air-dry bulk; pervious when free from impurities; blackish gray and plastic to sticky

from variations in amounts of well-disintegrated herbaceous aquatic-plant débris; brownish, loose, and mellow when permeated with fibrous roots from grasses, sedges, rushes, and other plants.

These structural and color characteristics are sufficiently well marked in some deposits to constitute three phases in this subtype. It usually forms a well-marked layer at the greater depth of certain basin deposits, but it has been found also as a surface soil material, notably in a number of river valleys in the New England States.

The plant remains are derived from diatoms and other vegetation of microscopic size and simple structure, such as desmids; green algæ and species of Utricularia, Lemna, Riccia, and others are members of the vegetation unit floating freely in the quiet water of ponds and rivers.

Agricultural practices and possibilities are relatively unknown. Species of Calamagrostis, Phalaris, and Carex form the dominant vegetation cover of siliceous deposits on meadows of which the subsurface soil consists of macerated peat materials.

Diatomaceous material has valuable abrasive properties. As "infusorial earth" it is often employed for filtering, insulating, nonconducting, or packing purposes, as an absorbent, and for making protective soundproof envelopes.

### COLLOIDAL TYPE.

"Lebermudde," "Saprokol," "Dy."

Finely divided, distinctly gelatinous, plastic organic débris, olive green, yellowish brown, or greenish brown in color; dark gray to blackish brown, hard, and of the consistency of horn when dry. The material is in large part probably a flocculation product rather than the result of chemical reaction or other transformation, since it has been found mainly in basins which are fed by ground waters containing lime in solution or which overlie a calcareous mineral substratum. There appears to be nothing in this type of peat that may be interpreted as of algal origin. The very small particles of plant remains are chiefly fragments from an aquatic vegetation which probably covered the open water area to the exclusion of other plant life. The organic débris seems to be derived largely from light-colored parenchymatous rather than lignitic tissue or waxy and resinous components. Algal filaments are present occasionally, but less abundant than spores, pollen, seeds of water plants, animal ejecta, and other derivatives. Representative data of a chemical nature are given in Table I.

The layer is a transitional one, since in position it occurs more commonly between a lower silty or clayey calcareous mudlike débris and an upper macerated type of peat.

DOPPLERITIC TYPE.
"Dopplerit."

Blackish, structureless, compact, somewhat plastic, and homogeneous débris of mixed origin. An organic complex (organic lime salt; calcic humate), which is partly an end product of disintegration combined with lime and which probably results from a reaction between disintegrating, oozelike and very finely divided fragments of a variety of herbaceous plants, soft, woody tissue, etc., in the presence of ground water from sedimentary limestones or calcareous drift. The type has been found also as a surface layer on peat lands which appear to have been subject to prolonged shallow inundation of water carrying organic débris in suspension. The material is hard when dry, resembling bitumen or lignite, occasionally of a shiny vitreous appearance resembling anthracite; it weathers into angular, irregular-shaped fragments which gradually break down into a fine black dust in overdrained fields. The chemical data in Table I are representative for this type of peat material.

A similar organic complex but mainly ferruginous in character is found in some peat deposits (ferric humate) which appears to arise in a like manner through the action of chalybeate ground waters.

## THE MARSH GROUP OF PEAT MATERIALS.

Types of peat material (autochthonous) from meadow stages of a vegetation series in treeless wet places with a water table near or slightly above or below the surface, or partially submerged during part of the year.

The peat materials are essentially fibrous and somewhat felty or matted, formed in the main from roots and rootlets of plants (radicellate peat). Macerated plant remains, seeds, fragments of various tissues, and woody components from shrubs are present in moderate or large quantities according to the degree of inundation of the area.

The types are derived from various vegetation units, such as sedges, reeds, cat-tails, rushes, and grasses. If water-formed layers of peat material and their wind-blown or otherwise transported drift components described above are absent in the profile structure of a peat deposit, it points to the fact that the conditions for the growth of plants and the accumulation of their remains are entirely different from those already discussed. The noteworthy characteristic is the presence of roots which traversed the old soil or the shallow bottom of mud. The network of roots, rootlets, and rhizomes with its entangled matted mass of aerial plant remains also shows that the area had an initial water table near the surface or above it during only a part of the year. To the degree in which the plants form a closed

association and the rise of the water table is favorable for their growth, they become buried as extensive or fragmentary layers, essentially intact and fibrous or partially disintegrated. On account of the slight shrinkage of the plant remains, the respective layers which are "built up" in this manner may constitute several feet of a deposit, but further increases in thickness practically cease unless there is considerable disintegration and shrinkage in the material or a rise in the ground-water level from any cause.

When an accumulation of structureless or macerated type of peat material formed in large part by aquatic vegetation units preceded and reached nearly to the water level, peat deposits of this class show as a rule a fibrous matted layer, more or less sharply differentiated in structure from the peat material below it. By the constantly advancing growth of semiaquatic and marsh plants the fibrous materials may gradually extend over the shoaling water, sink as their thickness increases, and thus give rise to filled-in deposits of peat. Water pockets are not uncommon as delimiting strata.

This has an important bearing upon drainage, tillage, and other operations, and upon the possible uses of the land. In planning drainage improvements it is well to remember that deposits not too well drained are safer than those overdrained and that in this respect the distance between ditches and tiles is usually more effective and important than their depth. For areas of greater depths of peat or with poorly disintegrated grades of fibrous peat material it is necessary to anticipate a gradual but certain subsidence to as much as one-fourth of the original thickness. The decrease in the elevation of the surface should be met, therefore, by a provision for deepening the gravity outlet or for drainage by means of pumps.

The marsh types of peat are among the most profitable for agricultural purposes, though several of them indicate in some instances the presence of salts which in sufficient quantity may injure certain cultivated crops. The nature of the mineral subsoil, whether clay or sand, may considerably affect the agricultural value and need for fertilizers, the former responding, it seems, more readily to phosphates, the latter requiring phosphatic and potash manures, and to some extent lime. Marsh or fen types of peat are easily cleared and brought under cultivation, and they are suitable for a variety of crops if carefully drained or if the drainage channels are provided with check gates. Some of the types when overdrained are apt to become brittle and easily break down to light-colored "mull" or granular peat dust. This is especially characteristic of fibrous sedge and of brown-moss (Hypnum) types of peat. Moreover, marked differences may arise from the preponderance of semiaquatic

débris undergoing weathering and disintegration. As surface material this blackish fine-grained component is almost impervious to water, probably due to the absorption of air. Windbreaks, preferably of alder, maple, and willow, are necessary to prevent injury from dust storms to seedling crops, but a rotation which includes broad-leafed crops or plants with a fibrous root system to hold the fine-grained débris would be more advantageous and would aid in maintaining a favorable water content at the surface of the soil if irrigation measures are not feasible.

The first crop to be planted deserves, therefore, careful consideration, as it materially affects the disintegration of the plant remains. On poorly disintegrated, fibrous phases of these peat types, potatoes and corn are considered desirable. Where droughts are of rare occurrence not much trouble has been experienced in keeping the ground water too low to injure crops of value in intensive modes of farming. Ferruginous peat material of these types would, however, prove more profitable if under cultivation for hay and pasture.

The value of these types for industrial purposes is dependent on several factors, most important of which are the degree of disintegration, the ash content, and the impurities. The blackish, compact, well-decomposed phases with less than 20 per cent of ash produce less soot or ether and alcohol soluble and pitchy substances than the types of peat which contain the resinous and waxy bodies (see Table I). They are therefore considered preferable for the manufacture of power gas in gas producers where by-products are objectionable and their recovery is not contemplated. As machine peat, thoroughly ground, pulped, and air-dried, they yield a fuel of good quality, generally near 3,500 calories; they are clean to handle, give a relatively intense heat, and are well adapted for smaller manufacturing or farming communities and for domestic uses. The brick-shaped blocks of machine peat that are allowed to air-dry slowly contract into a dense mass covered by a gelatin-like outer layer which is reported to be a hydrocellulose rather than a resinous substance; it renders the machine-made product almost impervious to water, compact, and more resistant to breakage.

The coarser textured, partly fibrous phases of peat appear to be preferable for composting and as a filler for tankage or a base for compounding with fine-ground mineral fertilizers. After excavation the moist peat material should be piled and stored in mounds 20 or 30 feet high and kept under cover if possible for at least six to eight months. During that time the plant remains shrink considerably in volume and undergo a slow internal heating, granulation, and carbonizing process, which may be aided artificially by means of pipes heated with "exhaust" steam. The material has been

profitably employed for various uses, including those essential to agriculture and as powdered peat for fuel in blast burners, for firing steam boilers, and for other purposes. It has not yet been shown conclusively that this material will produce nitrates on a large scale if inoculated with nitrifying microorganisms, but culture beds of these types of peat would probably be preferable to other media (5).

### REED-GRASS TYPE.
### "Phragmites peat," "Schilftorf."

Fibrous peat material, consisting mainly of a network of smooth and pustulate rootlets and stout hollow-stemmed, long, flat-pressed rootstocks (closed at the joints) of the tall reed-grass (*Phragmites communis*); to a less extent are present the plant remains from species of Typha, Phalaris, Glyceria, Carex, or Sparganium. Macerated aquatic débris is found in varying proportions. The material is light yellowish or reddish brown to rusty brown in color; older layers of this type are fairly compact, largely disintegrated, chocolate brown to blackish in color when exposed to the air, and frequently contain charred woody components. They are mottled in appearance when under poor drainage conditions, from infiltration and precipitation of sulphur or iron compounds.

The type is more commonly found in peat deposits of the Central and Middle Western States in layers of considerable thickness. As a peat-forming plant Phragmites is well distributed nearly throughout the United States, tolerant to brackish water and to ground waters which contain a variety of injurious mineral impurities in solution. This renders the surface peat soil liable to saline incrustations drawn from the deeper strata; it tends to retard or prevent the appearance of shrub and tree stages of vegetation and may result in injury to deep-rooting crops when the area is brought under cultivation. On some of the deposits overlying pyritous shale or drift derived from pyrite-bearing rock formations the presence of mineral acids may sensibly diminish the cropping value of the land. The accumulation of iron at the surface may continue, in part replacing the plant remains by ferric compounds and nodular concretions which vary widely in composition.

In Tables I and II have been summarized the more noteworthy data of a physical and chemical nature for this type of peat.

TABLE II.—*Physical characteristics of important types of peat.*

[Data from Zailer and Wilk (26-27).]

| Type of peat material.[1] | 100 parts of material. | | | | | | Specific volume weight of material in 1 liter. | |
|---|---|---|---|---|---|---|---|---|
| | Moisture free. | | | | Air dry, 25 per cent of water content, absorb— | | | |
| | Contain— | | Absorb— | | | | | |
| | Organic matter. | Ash. | Water. | Ammonia. | Water. | Ammonia. | Ash content. | Weight. |
| Sec. A.—Aquatic group. | | | | | | | *Per ct.* | *Grams.* |
| 1. Macerated type | | | | | | | | |
| 2. Colloidal type | | | | | | | | |
| 3. Doppleritic type | | | | | | | | |
| Sec. B.—Marsh group. | | | | | | | | |
| 4. Reed-grass type: | | | | | | | | |
| Phragmites peat (fibrous) | | | | | | | 14.65 | 217 |
| Poorly disintegrated | 86.02 | 13.98 | 888.1 | 0.89 | 666 | 0.67 | 11.80 | 277 |
| Partly disintegrated | 86.71 | 13.29 | 871.4 | .98 | 653 | .74 | 10.46 | 417 |
| 5. Sedge type: | | | | | | | | |
| Carex peat (fibrous) | | | | | | | 3.84 | 221 |
| Poorly disintegrated | 98.27 | 1.73 | 1,379.8 | 2.16 | 1,035 | 1.62 | 3.97 | 260 |
| Partly disintegrated | 96.03 | 3.97 | 1,422.4 | 1.09 | 841 | .82 | 3.51 | 288 |
| 6. Brown-moss type: | | | | | | | | |
| Hypnum peat (fibrous) | | | | | | | 7.61 | 95 |
| Poorly disintegrated | 92.86 | 7.14 | 1,506.8 | 1.22 | 1,130 | .92 | 5.73 | 187 |
| Partly disintegrated | 94.28 | 5.72 | 887.3 | 2.41 | 665 | 1.81 | 3.32 | 204 |
| Sec. C.—Bog group. | | | | | | | | |
| 7. Bog-moss type: | | | | | | | | |
| Sphagnum peat (fibrous) | 97.92 | 2.08 | 1,604.2 | 1.83 | 1,203 | 1.37 | 1.93 | 88 |
| Poorly disintegrated | 99.38 | .62 | 1,635.5 | 2.64 | 1,226 | 1.98 | .64 | 113 |
| Partly disintegrated | 95.87 | 4.13 | 524.1 | 2.02 | 393 | 1.52 | 3.21 | 157 |
| 8. Arrow-grass type: | | | | | | | | |
| Scheuchzeria peat | 96.16 | 3.84 | 1,210.3 | 2.24 | 908 | 1.68 | 3.80 | 162 |
| 9. Cotton-grass type: | | | | | | | | |
| Eriophorum peat | 99.46 | .54 | 974.3 | 3.46 | 731 | 2.60 | .59 | 121 |
| 10. Bog-shrub type: | | | | | | | | |
| Heath peat | 89.99 | 10.01 | 456.0 | 2.30 | 342 | 1.73 | 10.01 | 297 |
| Sec. D.—Swamp group. | | | | | | | | |
| 11. Alder type: | | | | | | | | |
| Alnus peat; poorly disintegrated | 98.35 | 1.65 | 564.5 | 3.83 | 424 | 2.87 | 1.60 | 287 |
| 12. Birch type: | | | | | | | | |
| Betula peat— | | | | | | | | |
| Poorly disintegrated | 97.91 | 2.09 | 741.8 | .97 | 557 | .73 | 2.18 | 242 |
| Partly disintegrated | | | | | | | 3.44 | 257 |
| 13. Deciduous-forest type | | | | | | | | |
| 14. Coniferous-forest type | | | | | | | | |

[1] Although no definite data are at present available regarding the physical characteristics of types corresponding to the numbers 1, 2, 3, 13, and 14, the designations of those types are here retained in order to show their relationship in the classification.

SEDGE TYPE.

"Carex peat," "Seggentorf."

(*a*) Light-brown or reddish to dark-brown, fibrous, felty peat material, mainly composed of finely fibrous roots and pustulate rootlets of sedges (*Carex* spp.); more or less uniform in appearance and compact, though porous; often recognized by the presence of the coarser fragments of (triangular) sedge culms; occasionally present are the plant remains and sheathed culms of *Scirpus* spp. or the matted rootstocks of *Juncus* spp. The macerated components from

aquatic-vegetation forms and the finely divided débris which contains seeds, pollen, spores, and chitinous and other fragments may be present in varying proportions. Older and more disintegrated layers vary in color from dark brown to brownish black and readily become granular when weathering.

The type is derived from a diffuse stage of sedge marsh or wet meadow, formed in part by rushes and other grasslike plants which are usually present in many peat deposits; they are characterized very frequently by the dense clumps or tussocks of *Carex stricta*. Semiaquatic plants are abundant in the water-logged depressions between the tussocks of sedges, while many herbaceous plants find lodgment in such places on the drier ridges and hummocks.

(*b*) A subtype which is more characteristic in the transition series to the bog group of peat materials consists similarly of a finely fibrous feltlike network from rootlets and underground scale-like leaves and stem portions of a variety of sedges, but usually includes the thickish rootstocks of the buckbean (*Menyanthes* sp.) and the threadlike stems of several bog plants. The material is grayish brown to dark brown in color. It is not easily distinguished from the peat material formed by sedges which occupy open-marsh meadows, except, perhaps, for the occasional resinous and waxy components from bog, heath, and other plants and in the fact that the lower contact layers are often poorly differentiated from the structureless material which formed below the floating sedge mat. Pockets of water are not uncommon.

The plant remains in the bog-sedge subtype show a rather widely varying admixture of sphagnum mosses, cranberry (*Vaccinium* spp.), and other heath plants. Among the sedges *Carex filiformis* is especially active on northern peat-land areas in extending the floating marginal platform of a bog meadow.

The material of poorly disintegrated sedge peat is quite resistant to cutting, plowing, and weathering. It is inclined under excessive drainage to form a mull, or dust, which is peculiar also to a few other types of peat material.

Various physical and chemical data are given in Tables I and II, among which are the striking differences in ether and alcohol soluble extracts.

### BROWN-MOSS TYPE.

**"Hypnum peat," "Astmoostorf."**

Brownish green to drab-colored, light, spongy, matted material, often laminated and porous in appearance, derived mainly from the entire plants of various species of Hypnum mosses or related forms and containing an interbedded admixture, in varying proportions, of finely fibrous rootlets from sedges, etc.

The material disintegrates rather poorly and becomes brittle when overdrained, breaking down into a dust, or mull. Older layers are blackish in color and appear more or less structureless.

The type is more generally a transition feature to the bog group of peat materials; it is found in peat deposits in the Northwestern States and seems to occur there in considerable thicknesses. In the Central and Eastern States it is found only in layers and pockets of irregular size, heavily admixed with the plant remains of species of Carex, Phragmites, and other peat-forming plants. Tables I and II contain the more important physical and chemical data for this type of peat.

### THE BOG GROUP OF PEAT MATERIALS.

Types of peat material (autochthonous) from bog-meadow and bog-shrub stages of a vegetation series in wet places, with the water table near or slightly below but rarely above the surface.

The plant remains are characteristically spongy and porous or matted-fibrous to wickerlike peat, somewhat resistant to disintegration, reddish, yellowish, and deep brown in color. The interstices are filled with a macerated débris in varying proportions, often soft and oozelike, in which fragments of cell complexes are usually well enough preserved to be determinable. The resinous constituents and the threadlike rusty brown root fragments of heaths with mycelial fungi are an important factor in lending the specific character and value to this group. In transition stages the finer débris or ground mass forms a considerable portion of the material, with intergradations from structureless plastic-appearing substances discerned with difficulty to clearly recognizable fibrous and woody fragments.

The materials are derived from vegetation units which appear first as scattered, more or less localized plant associations in the marsh stages of a peat deposit. It seems that the succession of marsh to bog has taken place far more frequently than recognized hitherto, since sections through the profile of the lower layers of peat deposits in many localities show clear evidence that the area was formerly occupied by marsh vegetation. Quite similar stratigraphic successions leading from marsh to bog recorded in the peat deposits of European moors have been recognized in this country. In lacustrine deposits, however, bog vegetation appears often as foreland communities and immediately following the semiaquatic stages of a vegetation series after the accumulation of macerated, structureless, water-formed peat has reached nearly to the water level. By means of much-branched interwoven underground stems and fibrous rootlets they border open water or completely surround it as a floating mat, which rises and falls with the seasonal variations in the water table

or sinks and becomes buried as a layer of fibrous peat firm enough to support trees.

Bog-plant associations may occur in marshy and wooded areas of valleys and uplands, and they may form definite sedge or "grass" bogs, "moss" bogs, and "heath" bogs under field conditions which inhibit the natural growth of plants other than the bog xerophytes. They are believed to be glacial relicts from a former more general distribution of boreal plants, some of which are represented in Europe and Asia by the same or closely related species. Most of these plants are now confined to an area extending from the north Atlantic to the Mackenzie basin in northern America, in which they attain their best development, and to locations with high atmospheric humidity. In their southern limits of distribution they maintain themselves, it seems, on account of soil conditions which indicate physiological drought as distinguished from physical drought. A discussion of the selective action of the soil stratum which allows bog plants to outgrow others, the effects on certain cultural plants used experimentally, and the possible causes of physiological drought offered in explanation of this fact has been published elsewhere (5; 20).

Where climatic conditions, such as high atmospheric humidity, are especially favorable these plant associations may spread laterally over adjoining land surfaces or move up well-defined slopes of low hills. If the ground water, designated *aerial* as distinguished from *telluric*, rises in proportion, they may react upon other vegetation units. In northern countries of Europe they build up high moors, invade forests, and destroy with their accumulation a part or all of the tree covering.

The peat materials of this group weather slowly if improperly drained, and they require fall plowing and freezing, with frequent packing by heavy rollers, to maintain good tilth and the upward movement of soil water. Of considerable practical moment is the fact that as a general rule the amount of mineral matter is very low in these types and that applications of complete mineral fertilizers and stable manure for inoculation with beneficial soil microorganisms appear to be more effective in establishing a normal balance of plant-food constituents and of bacterial action than in any of the other groups and types of peat material. The cultivation of grasses for hay and pasture or of potatoes as a first crop and corn, preferably for silage purposes, are known to be profitable in the preparation of these peat types for other farming practices.

The shrinkage on dewatering is very much slower than that which occurs when marsh or swamp and aquatic types of peat are subjected to drainage operations. With underlying water-formed

plant remains or with water pockets as delimiting layers, the accumulation of bog peat may settle to a considerable extent. A change in the elevation of the gravity outlet or drainage by pumping may later be the only feasible method of relief. It is important, therefore, in designing drainage improvements to anticipate a subsidence of 10 to 25 per cent in the original profile of the deposit. Many bog peat-land areas are now deteriorating because the drainage systems laid out by an earlier generation have not provided for this shrinkage or have been allowed to get out of repair. Where seepage waters and springs arise along the hills bordering the valley or basin, intercepting ditches are extended along the lower edge of the high lands and provision is also made for the annual removal from the drains of any iron or other compound, sand, silt, or invading vegetation. The washing in of mineral impurities should be restricted to the lateral ditches. Saline constituents when present in these types of peat tend to appear and to accumulate at the margins as iron pan and bog iron or in the form of irregular patches of concretions near the ditches or overlying subterranean drainage waters and springs. The ground-water supply, springs, and the mineral subsoil especially require attention in regions of rock formation which contain an excess of soluble salts.

Only the fibrous and poorly disintegrated surface layers of these types are of value as litter and mull if properly dried and shredded (Table I). A rapidly growing industry in Europe is using these plant remains for manufacturing purposes, and they are greatly to be recommended for use in this country. The materials are shredded by simple tearing machinery and passed through rotary sieves to separate the finer mull from the fibrous material, which may be used for bedding live stock, for insulation and packing, in the manufacture of special grades of charcoal for metallurgical purposes, of pulp, pads, fiber, or alcohol (by converting cellulosic components into sugar with diluted sulphuric acid). Shredded peat material from certain species of sphagnum mosses, relatively free from inorganic impurities and of uniform composition, has been used as surgical dressings for wounds and as pads for patients with dysentery on account of its high absorbent value. It is in many respects a good substitute for medicated cotton.

There is an increased demand in Europe for sphagnum mull products, the particles of which are not larger than one-eighth of an inch (3 mm.) in diameter, as an ingredient with molasses in stock feed for fattening purposes and to prevent disorders. Mull from sphagnums as well as from Hypnum mosses and fibrous sedge peat has been employed profitably for packing, as an effective deodorizer and disinfectant for use in receptacles holding waste animal matter, and

as an absorbent of gases (Table II) and of the valuable nitrogenous material of stables. The advantages of mull as powdered fuel in blast burners are considerable and of great importance for certain localities. The firing is reported to give a higher fuel efficiency and is relatively smokeless on account of the intimate mixture with the air or gases used. Moreover, there is the possibility of regulating the supply required for complete combustion. The change from oxidizing to reducing flame and from low to very high temperatures can be accomplished quickly.

The poorly disintegrated phases of these types of peat make a very inferior grade of fuel. With the same treatment through pugging or macerating machines, they make a bulky product, light in weight (Table II), dusty and brittle when dry. The well-disintegrated layers of the same plant remains form a much finer grained, uniform, compact mass. The methods and machinery employed for working bog types of peat material, either for use as litter and mull or for heat and power, as machine-shaped air-dried blocks of peat for direct firing, for gas generators, or for distillation products, should therefore be determined in each individual case by a careful preliminary examination. It is obvious that only such deposits permit successful development as provide not only the quantity and quality of peat materials required, but if utilized would not cause an impairment of the land value of the underlying mineral soil. In Europe the most profitable utilization has been a combination of both the technical and the agricultural possibilities to which the peat area may be put during and after the removal of these materials.

### BOG-MOSS TYPE.
### "Sphagnum peat," "Bleichmoostorf."

Loose, spongy, fibrous or matted-porous, often layered plant remains from the entire plants of different species of sphagnum mosses, usually with an admixture of other bog-plant material; light grayish brown, yellowish, or deep brown in color, according to the degree of disintegration and the species of moss predominating. Where the development of the layer has been gradual and the extension of the mat has become anchored or has been built up, the material consists of poorly disintegrated remains of moss with relatively small amounts of macerated débris and finely fibrous sedge peat. Fragments from heath plants are present in varying quantities.

In the floating-mat phase and in the deeper layers of bog-moss peat which are more advanced in stages of disintegration, the plastic or oozy component occurs in greater abundance. The material is dark brown to blackish in color and shrinks considerably upon drying.

Except in a few Northern States and in Canada the built-up layers of bog-moss peat are rarely of great thickness or purity in plant composition. Other peat-forming plants which usually accompany sphagnum mosses are the cranberry (*Vaccinium* spp.), sundew (*Drosera* spp.), arrow grass (*Scheuchzeria* sp.), cotton grass (*Eriophorum* spp.), *Rynchospora* spp., *Menyanthes* sp., various species of sedge (Carex), and others (5).

The rarity of sphagnum peat is noteworthy and, together with the rather restricted occurrence at the present day of "moss" bogs as compared with sedge or "grass" bogs and "heath" bogs, is interesting, since sphagnum mosses are by many considered to be the starting point and the type plant association of peat deposits.

Considerable work has been done upon the physical and chemical features of this type of peat material, some of which has been summarized in Tables I and II. Other correlative phenomena have been discussed in a previous publication (5, p. 386–392).

ARROW-GRASS TYPE.
"Scheuchzeria peat," "Beisentorf."

COTTON-GRASS TYPE.
"Eriophorum peat," "Wollgrasstorf."

These two types are generally a composite in the peat accumulations of this country. The plant remains appear to be rarely of the thickness of accumulation or homogeneity in composition recorded for European deposits. They are derived from bog plants which associate with or follow closely a zone of the sphagnum-cranberry stage of bogs in our northern peat deposits.

The peat material is rusty to reddish brown, rather coarsely fibrous from plant remains, such as roots, rootlets, leaf bases, and leaf fibers of the wool or cotton grass (*Eriophorum* spp.) and of the arrow grass (*Scheuchzeria* sp.), roughish from the clustering of culms, with varying admixtures of the grayish to dark-brown partially disintegrated sphagnum mosses and the finely threadlike material from cranberry and similar heaths.

The coarser fibered Eriophorum component is quite resistant to disintegration and to cutting processes. When relatively pure in composition Eriophorum peat is deemed of considerable value for textile purposes, the manufacture of cloth, and similar technical uses.

The type of material in which the plant remains from arrow grass preponderate consists of a reddish finely fibrous network of rootlets inclosing thin scalelike leaves and leaf bases of this plant; the peat material is inclined to be brittle when dry and breaks down into mull or peat dust. Chemical and other data are given in Tables I and II.

BOG-SHRUB TYPE.
"Heath peat," "Reisertorf," "Heidetorf."

Reddish to rusty brown wickerlike peat material, partly finely fibrous from rootlets, but with numerous small twigs forming a prominent proportion. The woody fragments are derived from roots, stems, and branches of various bog shrubs, mainly heaths; the macerated ground mass is more or less resinous.

The type is often accompanied by a marked occurrence of highly ferruginous impurities either distributed through the mineral subsoil as a hard impermeable layer or pan or in the form of bog iron on and near the surface. In coastal climates the bog shrubs show beneath the peat material a layer of leached-out whitish or gray sand of varying thickness; underlying it is a characteristic blackish or yellow to rusty brown iron-stained sand, which often contains much of the mineral material and organic colloidal complexes leached from the upper sandy layer. The soils when denuded of their surface covering of peat material appear to be unsuitable for ordinary farming practices unless well handled. Pans, however, are by no means confined to heath bogs; they often occur in forests and on certain marshy and cultivated sandy soils.

The plant remains in heath peat are derived largely from bog shrubs, among which *Andromeda* sp. and *Cassandra* (*Chamaedaphne*) sp. are the most prominent of the ericaceous plants. Other genera, such as Ledum, Vaccinium, Myrica, and Kalmia, are less numerous in individuals and not so general in their distribution as to give rise to specific types of heath peat. In some of the sphagnum-cranberry bog meadows they are present in sufficient numbers to make a dense thicket, thus shading and even destroying the vegetation which covers the ground. The plants spread rapidly by means of long horizontal underground stems, from which arise at intervals erect leafy branches.

*Empetrum nigrum* and *Calluna vulgaris* occur very rarely on bogs in the United States, but they are among the low evergreen heath shrubs in the bogs of Canada and occur generally on the bogs or high moors of northern European peat deposits.

The chemical and other data cited in Tables I and II relate to heath types of peat on high moors.

THE SWAMP GROUP OF PEAT MATERIALS.

Types of peat material from coniferous trees and from deciduous shrub and tree stages of a vegetation series on a wet substratum with the ground-water table generally below the surface during part of the year, as in bog forests and pond swamps, or partially submerged, as in river and coastal swamps.

The peat materials are characteristically a shrub or a forest litter. The greater proportion consists of woody material; roots, trunks of trees, branches, bark, twigs, etc., in a tangled mass, are in all stages of disintegration and more or less in such a state of preservation as to be determinable. In this are the remains from leaves, ferns, mosses, scales, the rootlets of herbaceous plants, and fungal hyphæ and spores more or less plainly recognizable. The material which fills the interstices consists of semidecayed weathered tissue and granular débris of great variety, comparable in structure with amorphous water-formed peat material, but free from the more obviously transported drift of lacustrine and valley or estuarine deposits.

The most critical factor in origin is the position of the water table. Trees instead of herbs and shrubs take possession of a wet marsh or bog area and gradually become the dominant peat-forming plant cover if the average water level during part of the time is sufficiently far below the surface of peat accumulation to favor weathering and longer periods for decay and for the products brought about by beneficial bacteria and fungi.

The deciduous-tree stage forms the end of the vegetation series; it indicates that an approximate balance is maintained between the amount of peat accumulation and the rise of the water level favorable for the growth of trees and that disintegration and loss of plant remains go on each year at about the same rate as the addition to the deposit made from the mature forest. Only when there is a marked and sufficiently prolonged elevation of the water table from any cause will plants of other vegetation stages reappear, establish themselves, and begin again the accumulation of peat materials.

Many factors may operate to affect the relationship of the water level to the surface, and the resulting types of organic material may vary, therefore, quite as much from climatic and other regional changes as from local features or artificial obstructions. A number of layers of forest litter in a peat deposit containing stumps and roots of trees naturally must be interpreted to indicate an equal number of modified field conditions for peat accumulation.

The presence of roots of trees in the substratum soils of a peat deposit or its bottom muds and the details of stratigraphic sections are features of considerable practical importance. They point to the fact that the area under consideration is in widely different condition for peat deposition and for the disintegration of material from that of filled basins. Originally in a land area with drainage well established the water table became elevated, probably through varying coastal subsidence, accompanied perhaps by irregularities

in barrier formation or, more likely, with the accumulation of plant remains, and it practically maintained itself over the area of active peat formation in close adjustment to the growth of the plants holding back the natural drainage. Areas of that class of peat deposits can be drained to the bottom and rarely need the more elaborate drainage measures which aim to reduce the amount of overflow in swamps and marshes resulting from river inundation.

Attention needs to be called to the fact that the dominant timber component alone is not always significant of the capabilities of these types of peat material. The plant remains derived from evergreen shrubs, such as the azalea and rhododendron, or from deciduous undergrowth in forests may alter the value of the material considerably. This is well illustrated in the distinction made by some authors between the "mild humus" characteristic of deciduous forests, well aerated and containing beneficial soil organisms, and the "raw humus" found in coniferous forests in which decay-producing organisms are usually less abundant.

ALDER-WILLOW TYPE.
"Alnus-Salix peat," "Bruchwaldtorf."

BIRCH TYPE.
"Betula peat," "Übergangswaldtorf."

Brown to chocolate-brown peat material, wickerlike in appearance on account of the numerous small twigs and branches of alder (*Alnus* spp.), willow (*Salix* spp.), and other species of deciduous shrubs which form a considerable portion in the fibrous or fragmental plant remains. The woody components often consist of bark and other recognizable, slowly disintegrating parts from birch (*Betula* spp.), but with the exception of the resinous components the material is as a rule relatively soft, easily cut, and tends to become brittle and granular when dry, breaking down into a blackish coarsely grained débris. Material which is well disintegrated or contains a large proportion of plastic ground mass takes on a compact structure and often resembles a hard substance when dry.

The plant remains are derived from shrubs, among which the alders, buttonbushes, and willows are the most common. Birch and ericaceous heath shrubs appear to be more numerous in individuals on peat deposits of the Northern States and in European countries.

The analyses presented in Tables I and II are intended to point out some of the features of practical value to agriculture and to technical interests.

DECIDUOUS-FOREST TYPES.
"Laubwaldtorf."

Loose, mingled débris of partly decayed branches, twigs, bark, and other aerial parts of plants falling to the ground and becoming in-

corporated in a more or less disintegrated leaf mold, which contains also the remains of herbaceous forms, ferns, and other vegetation growing in a mature hardwood forest. The older material of the layer is usually brownish black, woody, granular, with an abundance of fungal hyphæ. This débris characterizes the more fertile area, a large proportion of which is often brought under cultivation with a small expenditure for fertilizers on account of the finer texture of the well-weathered material and its aerated condition.

The types of most frequent recurrence but which at present must remain without further characterization are the maple-ash-elm (Acer-Fraxinus-Ulmus) type in swamps and bogs of the Central and Northeastern States, often associated with oak (*Quercus* spp.) and basswood (*Tilia* sp.) or with conifers, and the gum-maple (Nyssa-Acer) type in the swamps of the Southeastern States. The data in Table I serve to show the relative value of the European type of deciduous-forest peat.

### CONIFEROUS-FOREST TYPES.
"Föhrenwaldtorf."

Reddish brown plant parts from evergreen trees or from a mixed stand of conifers and deciduous forest trees which differ much in their resistance to weathering and decay agencies. The proportion of fibrous or leafy material and of weathered products from shrubs and herbs is quite variable. The ground mass in which the more resistant components are embedded is soft, plastic, and under moderate draining conditions becomes granular rather slowly. In overdrained deposits it dries and shrinks greatly and frequently takes on the consistency of a compact substance, impervious to water, especially when resinous material comprises an important element in the woody components. Experience indicates that coniferous peat materials are likely to be of low value for intensive farming purposes, even several years after clearing.

For each geographical or climatic district there are usually representative tree species which establish themselves, first scattered, then in a zone near the shore of lakes or valley channels, and eventually cover the entire peat-land area. As they grow taller they intercept a large amount of light and thus eliminate and displace the herbaceous and even shrubby undergrowth. The water of a heavy rainfall is held back sometimes to a considerable depth by the dense growth and tangle of fallen vegetation, thus extending the swamp conditions over adjoining areas. The larger number of trees have a shallow superficial root system, which may be removed by various methods of clearing, such as brushing, blasting, pulling, or burning. The plan of "brushing out" the land, plowing shallow the first time, gradually increasing the plowed depth from year to year, and seed-

ing the land to grasses and clover with rye or oats is believed to be the cheapest and best of any of the several methods practiced.

The several types of coniferous forests, such as the tamarack (*Larix* sp.), the northern white cedar or arbor vitae (*Thuja* sp.), and the spruce and pine (*Picea-Pinus* spp.) of northern bogs, the cedar (*Chamaecyparis* sp.) and the cypress (*Taxodium* sp.) of coastal and southeastern swamps, or the mixed type which is characterized by various conifers and deciduous hardwood species, must remain at present without further description. In texture and color the several peat materials appear to have much in common, though they are derived from the dominant species of trees representative of the region. The sharper contrasts are undoubtedly more prominent in the woody and resinous components and other plant remains, as well as in the condition of their decay and in the manner of the accumulation, that is, whether the deposits are the result of river inundation or formed in isolated tracts, fed by seepage and springs, where drainage features are correspondingly very different. Table I contains the more important chemical data for a type of European conifer-forest peat.

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